Domestic
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U.S. ARMY SOLDIER AND BIOLOGICAL CHEMICAL COMMAND

A Comparison of Decontamination Technologies for Biological Agents on Selected Commercial Surface Materials

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BIOLOGICAL WEAPONS
IMPROVED RESPONSE PROGRAM

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SBCCOM

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EXECUTIVE SUMMARY

In response to growing concerns regarding domestic terrorism, the 104th Congress passed Public Law 104-201, the National Defense Authorization Act for fiscal year 1997. In addition to providing our nation's first responders with training regarding emergency response to weapons of mass destruction, this legislation required that the Secretary of Defense develop and implement a program for testing and improving the responses of federal, state, and local agencies to emergencies involving biological and chemical weapons. As a result, the U.S. Army Soldier and Biological Chemical Command of the Department of Defense, in partnership with the Department of Health and Human Services, the Federal Emergency Management Agency, the Federal Bureau of Investigation, the Environmental Protection Agency, and the Department of Energy, developed the Biological Weapons (BW) Improved Response Program (IRP). This partnership was formed to assist all agencies with their responsibilities in responding to a biological incident.

The BW-IRP is a multi-year program designed to identify, evaluate, and demonstrate the best practical approaches to improve BW domestic preparedness. Through the use of multi-agency workshops on bioterrorism response the BW-IRP developed a response template that could function as a model for cities to use when developing their own bio terrorism response plan. Along with the medical response template, 28 gaps in biological warfare response were identified. One response gap identified was how do you decontaminate a public building after a bio terrorism attack. This test and associated report address the gap of how to decontaminate a building that has been contaminated with a biological agent.

This study evaluates available technologies (mostly research-scale) on the basis of to what level these technologies reduce the spore contamination on panels of different materials, which represent office environments. The testing platform consisted of six vertical surfaces, each made of a different material which could be commonly found in a typical civilian office environment. These test surfaces were uniformly contaminated with the bacterial agent simulant, *bacillus globigii*, BG and then sampled to determine the concentration level of the contamination at time zero (t=0). The test participants decontaminated the panels using their technology and procedure. The following day, the test panels were sampled again by swabbing to check for surviving BG spores.

Performing best in the overall rankings were University of Michigan (U.Mich.), Sandia National Laboratories (SNL) and Lawrence Livermore Laboratory (LLNL). The data suggest that the material surfaces most receptive to decontamination of agent simulant BG are Painted Metal, Painted Wallboard and Panel Fabric. The decontamination technologies were less effective on the porous surfaces. No technology was able to fully-decontaminate all surfaces in this test.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

A COMPARISON OF DECONTAMINATION TECHNOLOGIES FOR BIOLOGICAL AGENT ON SELECTED COMMERCIAL SURFACE MATERIALS – SUMMARY REPORT

1.0 INTRODUCTION

In response to growing concerns regarding domestic terrorism, the 104th Congress passed Public Law 104-201, the National Defense Authorization Act for fiscal year 1997. In addition to providing our nation's first responders with training regarding emergency response to weapons of mass destruction, this legislation required that the Secretary of Defense develop and implement a program for testing and improving the responses of federal, state, and local agencies to emergencies involving biological and chemical weapons. As a result, the U.S. Army Soldier and Biological Chemical Command of the Department of Defense, in partnership with the Department of Health and Human Services, the Federal Emergency Management Agency, the Federal Bureau of Investigation, the Environmental Protection Agency, and the Department of Energy, developed the Biological Weapons (BW) Improved Response Program (IRP). This partnership was formed to assist all agencies with their responsibilities in responding to a biological incident.

The BW-IRP is a multi-year program designed to identify, evaluate, and demonstrate the best practical approaches to improve BW domestic preparedness. A multi-agency team, comprised of over 60 experienced emergency responders, managers and technical experts for local, state, and federal agencies from around the nation, was assembled to execute the program. A series of 5 workshops provided the group with biological attack scenarios that progressively increased in severity. The group used the scenarios to develop a response template that could function as a model for cities to use when developing their own response plan. Along with the medical response template, 28 gaps in a biological warfare response were identified. One response gap identified was how do you decontaminate a public building after a bio attack and how do you determine when and/or if the building is clean enough for people to return. This test and associated report address the gap of how to decontaminate a building that has been contaminated with a biological agent.

While sterilization, as applied to pharmaceutical products, foodstuffs, and microbiology laboratory procedures, is well understood, decontamination of biological warfare (BW) agents in a domestic environment has received little study. The Institute for Defense Analysis (IDA) performed an intensive literature review, sponsored by the Environmental Protection Agency (EPA), to identify possible biodecontamination protocols and material. Their report concluded that there were no current protocols to decontaminate an office or workspace or an entire public building for bioagents.

Commercial sterilization requires a reduction of six logs (99.9999 percent) or greater. However, there is a gap in understanding how a large, or open environment such as an office should be treated to remove the residual hazard created by the release of a biological agent.

In a military scenario that follows U.S. Army Regulation (AR) 60-75 "NBC Survivability of Army Personnel and Materiel," an initial contamination density must be reduced by a minimum of 200-fold, with no more that 500 spores/m^2 remaining. To address the issue of what level of biological decontamination is achievable in a civilian office-type situation, the Life

Sciences Test Facility (LSTF) at West Desert Test Center (WDTC), Dugway Proving Ground (DPG), was tasked by SBCCOM's Domestic Preparedness Office to provide a technical testing platform for the evaluation of a variety of approaches to biological decontamination.

2.0 TEST OBJECTIVE

Compare the efficacy of eight decontamination technologies and/or systems to maximally reduce the level of *Bacillus globigii* (BG)) spores (a BW agent anthrax simulant) on six types of materials commonly used in office environments.

3.0 TESTING OVERVIEW

This study evaluates available technologies (mostly research-scale) on the basis of to what level these technologies reduce the spore contamination on panels of different materials, which represent office environments. Information on available technologies was collected from the Wide Area Decontamination Study suggestions from the Joint Services Materiel Group (JSMG), and from information gathered from the Decon 99 conference in Nashville, TN, May 1999. Organizations that had technologies with biodecontamination abilities were contacted and requested to provide laboratory data that supported their claims of biodecontamination success. A panel of DoD technical experts aided the BW-IRP in selecting the technologies to be included in this test.

The testing platform consisted of six vertical surfaces, each made of a different material which could be commonly found in a typical civilian office environment. These test surfaces were uniformly contaminated with the bacterial agent simulant, BG. These surfaces were then sampled to determine the concentration level of the contamination at time zero (t=0). These test surfaces were decontaminated by test participants, who using their proposed decontamination methods. The following day, the test surfaces were sampled again by swabbing to check for surviving BG spores.

4.0 CANDIDATE DECONTAMINATION MATERIALS/SYSTEMS

The decontamination technologies are listed below. The participants provided these brief descriptions of their technology. Technology descriptions were kept brief and generic because proprietary information was involved in most cases.

4.1 Diligen II (DII)

DII is a system utilizing ozone and moisture, which is power-charged by energy supplied from ultraviolet (UV) lamps operating at 254 nm wavelengths, to produce an output of highly oxidative gaseous species. This gaseous mix functions as an advanced oxidative system. In tests, it exhibits deactivation of microorganisms at a rate of 30 to 50 percent higher than ordinary ozone alone. There are few moving parts to this system. All gaseous outputs are eventually destabilized and recombine to form oxygen and water plus carbon dioxide as a byproduct of any reaction with microorganisms.

4.2 Reactive Nanoparticles

Nantek, Inc. of Manhattan, KS has developed a decontamination technology that uses reactive nanoparticles of metal oxides that are reactive toward both chemical and biological agents. They are easily dispersed and stay airborne for prolonged periods of time. Results show that halogenated formulations of nanoparticles are effective against gram-positive bacteria (*Bacillus globigii, Bacillus cereus*), gram-negative bacteria (*Escherichia coli, Erwinia herbicola*), toxins (aflatoxin B1), and simulant of a human virus, MS2 bacteriophage.

4.3 L-Gel

Lawrence Livermore Laboratory, Livermore, CA, has developed a decontamination technology, L-Gel, which consists of a gelled decontamination material, which is sprayed onto the surfaces to be decontaminated. The gel is designed to adhere to vertical surfaces and the undersides of horizontal surfaces. Upon contact with biological agents, the cell membrane of the agent is damaged through oxidation of the organic lipid layers, which kills the agent.

4.4 University of Michigan Nanotech

The University of Michigan, Center for Biological Nanotechnology has developed a novel broad-spectrum antimicrobial nanoemulsion. The emulsions kill Anthrax spores first by initiation of germination without complete outgrowth, which weaken the spore wall. This is followed by spore disruption and disintegration. This process starts in about 30 minutes and the complete killing will be achieved in 2-3 hours. The nanoemulsions are non-irritant, non-toxic and environmentally friendly. They have a prolonged action, with a shelf life of 2 years. They do not require any special storage except avoidance of freezing and drying.

4.5 Aqueous Foam

Sandia National Laboratories (SNL), Albuquerque, New Mexico, has developed a decontamination technology using aqueous foam. Testing has shown that the foam can neutralize/kill chemical and BW agents such as soman (GD), persistent nerve agent (VX), mustard, and anthrax.

4.6 Activated Solution of Hypochlorite (ASH)

The Naval Biological Laboratory (NBL) developed the Activated Solution of Hypochlorite (ASH) during 1967 and 1968. Several formulations are reported in the literature; however, the general formula is, by weight percent, calcium hypochlorite (0.5), sodium dihydrogen phosphate (0.5), Triton X-100 (0.05), and water (98.95). Researchers have shown that ASH is effective at killing BG. ASH has been applied to test substrates using a garden sprayer..

4.7 GD-5 Decontaminant Solution

Odenwald Werke Rittersbach, GmbH of Elztal-Rittersbach, Germany has developed a decontaminant solution, GD-5, which is a mixture of aminoalcholates and a non-ionic surfactant. The detoxification effect of these components is based on the nucleophilic substitution of all chemical warfare agents.

5.0 PANEL TEST CONDITIONS AND PROCEDURES

The testing platform consisted of 5 days (Table 5-1). The morning of the first day was used to prepare the proper environmental hazard assessment documentation. Test participants were also instructed on how the test would proceed. Participants were provided with their first set of contaminated panels which allowed them to work out the logistics of application of their technology and to make sure all necessary materials provided by LSTF were available This first day of testing also provided time for the LSTF personnel to determine that they had the proper resources available. Data was collected for this day but was not used in the test analysis. The subsequent 4 days were actual data collection days. Test participants were provided with newly contaminated panels each day. Each participant's data was evaluated by comparing colony forming units before and after decontamination.

5.1 Surfaces Used in Test

16 inch x 16 inch panels of the following materials were contaminated using a sprayed aerosol of BG spores. The aerosol was directed at the surface of the panel the evening prior to each trial.

- Acoustic ceiling tile
- Commercial carpet, tightly woven
- Fabric-covered office partition panels
- Smooth latex painted wallboard
- Thirty-day-old concrete block slab (prepared by LSTF staff)
- CARC (chemical agent resistant coating) -painted metal

CARC-painted panels were used as the control for this study because this coating was developed to provide protection of surfaces from chemical and biological warfare agent contamination.

5.2 Contamination Process

BG contamination was applied inside a chamber in Building 2026 of the LSTF. A BG aerosol spray, from a "Badger® Airbrush 100CL" with a fine nozzle, was directed from a distance of about 0.46 m (18 in) perpendicular to the surface of vertically suspended panels. Each panel received four passes with the aerosolspray. The target value for BG deposition densities was in the range of 10^7 to 10^8 colony forming units (CFU)/sample area (4 in^2). The contamination level on each panel was determined as described below.

This test evaluated surfaces contaminated by a sprayed aerosol directed at surfaces and did not consider heavier contamination that might be found in containers or in spills.

5.3 Pre-Decontamination Sampling

The contaminated panels were allowed to sit overnight at room temperature to dry, approximately 18 hours, The next morning, the day's test panels were transported to the structure known as the Suppressive Shield at DPG. Each contaminated panel was sampled at three different locations to determine the initial contamination level, time zero (t=0). A sterile polyfiber swab was rolled back and forth within a 2-in. × 2-in. area (Figure 5-1) and placed into a test tube containing 20-ml of phosphate buffered saline (PBS) containing sodium thiosulfate and 0.1% Triton X-100. The addition of Triton X-100 significantly decreases spore clumping. The thiosulfate neutralized the hypochlorite moieties, which could affect the bacterial growth. The test tubes containing the swab samples were stored at 4°C until processed 24 to 48 hours later. The locations where the samples were taken were not identified to test participants. The test area did not contribute any secondary bacterial contamination to panels.

Figure 5-1. Sampling a Contaminated Surface

After the pre-decontamination samples were taken, the panels were vertically suspended against a 0.61-m x 2.43-m (2 ft × 8 ft) section of plywood (Figure 5-2), about 1.07 m (3.5 ft) above floor level. The concrete panel was horizontal and at floor level.

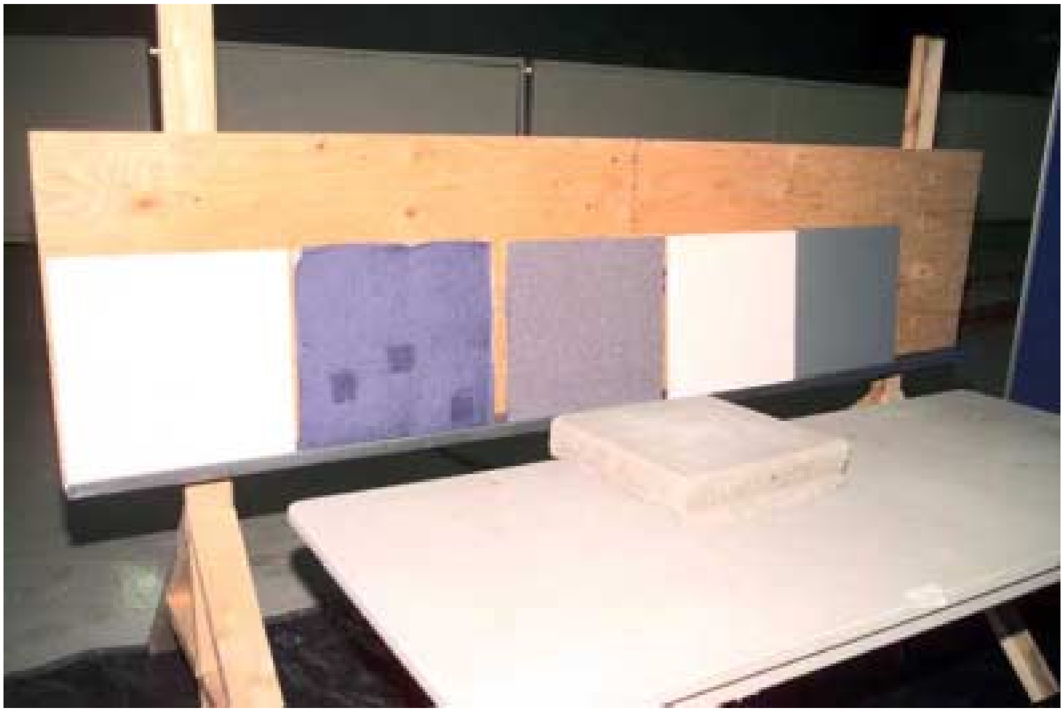

Figure 5-2. Test Panels Ready for Decontamination

5.4 Decontamination

The next morning (approximately 18 to 24 hours later) the panels were made available to the participating decontamination technology representatives. Each group of representatives was given a set of panels to decontaminate according to their procedures and protocols. All panels, except the concrete slab, remained in a vertical position through out the decontamination process. The concrete slab was tested on the floor.

The participants were divided into two sections:

- Participants whose decontamination technology does not require respiratory protection comprised Section 1.
- Participants whose decontamination technology requires respiratory protection comprised Section 2.

The Section 2 participants whose technology required respiratory protection, completed their decontamination activities after Section 1 participants.

Figure 5-3. Decontamination Technologies Setup

Figure 5-4. Application of BG Spores to Panels

When a decontamination process was declared completed by the participant, they left the immediate area of the test panels

The decontaminated panels were allowed to sit in the Suppressive Shield building undisturbed overnight. The panels were sampled on the morning after the decontamination process was completed in the same manner as described in Section 5.3. There was no contamination detected that could be attributed to test facility.

This process of contamination, decontamination, and sampling was performed four times using new test panels for each trial. The first trial was used by the testing staff and the participants to familiarize everyone with the test process and to confirm that all potential hazards had been addressed. The next four trials were recorded as test data, representing the natural change in bacteria count during the time of testing.

A "no treatment" effect was measured each day using a control set of contaminated panels, which received no decontamination treatment. Samples were taken in the same manner as previously described for test panels. These samples represented the natural change in contamination over time.

5.5 Anthrax Simulant

The surrogate organism used during this test was the spore-forming bacterium *Bacillus globugii* (BG). This bacterium closely simulates *Bacillus anthracis*. BG is gram positive, durable spore-forming, common in certain soils, non-infectious, easily grown in culture and easily detected. BG grown in trypticase soy agar (TSA) grows into a distinctive colony, which is easily identified visually with the naked eye.

5.6 Microbiological Assays

The concentration of BG spores (pre and post decontamination, Section 5.3) was determined by a standard (ref. 1) plate count on TSA. Aliquots of the appropriate dilutions of each sample were plated in triplicate.

The spore suspension was serially diluted in a sequence between 10^0 to 10^6 using phosphate buffered saline (PBS), pH 7.0. This dilution was taken into account when calculating the bacterial population.

A volume of 0.2 ml of the diluent was delivered to each plate and spread using standard technique. The spore population was quantified by culturing, in triplicate, on TSA plates that were prepared by LSTF prior to the test.

The plates were incubated at 37°C for 24 hours then counted visually by trained personnel. The average number of bacterial colonies and the standard deviations were determined.

5.7 Colony Counting

For this test, the plates were counted manually. Only plates having 30 to 300 colonies were considered in determining the plate count. The goal was to have at least one dilution provide colony counts between these limits, but if the total number of colonies was less than 30 from the undiluted sample, the 30 to 300 rule was disregarded, and the results 0 to 30 were recorded according to Standard Methods (ref. 2). The bacterial count per milliliter was computed by multiplying the average number of colonies per plate by the reciprocal of the dilution used. The results were reported as colony forming units (CFU) per milliliter. If plates from all dilutions of any sample had no colonies, the count was reported as less than one (<1) times the reciprocal of the corresponding lowest dilution. If the number of colonies per plate exceeded 300, the count was reported following the rules for estimation cited in heterotrophic plate count (9215) of the Standard Methods.

6.0 RESULTS AND ANALYSIS

To compare the decontamination capability of eight decontamination systems on six types of material surfaces, the statistical t-test was applied. The underlying assumption was that the residual population mean approximates a normal distribution for each type of panel surface.

Each of the six types of panel surfaces was analyzed separately. The analysis began with calculation of the surface-type (cement, carpet, etc.) residual mean for each panel surface (the average contamination remaining on panel after decontamination). The surface-type residual mean is the pivotal measurement that allows the decontamination systems to be compared. It is the mean of all the plate counts taken for a particular condition, expressed in terms of colony-forming units per panel.

The values of surface-type residual mean are shown in the following sections, for each technology, before and after decontamination. The variability of the plate counts from each panel is indicated in each table by the standard deviations of the values from which the means are calculated. The decontamination participants are arranged in the charts and tables in decreasing order of decontamination effectiveness.

The hypothesis, criterion (table t-value), and decontamination system ranking are part of each surface panel evaluation. To obtain the t-value, a 0.05 level of significance was used for all criteria. Emphasis was placed on the comparison of the results as opposed to whether or not the null hypothesis was accepted or rejected. The ranking and t-values are shown in tables for each surface-type.

6.1 Cement

The ranking and t-values for each technology are presented in Table 6-1. Results of the decontamination tests of cement panels are summarized in Figure 6-1 and Table 6-2.

Table 6-1. Decontamination Ranking for Cement Panels

Ranking	Decon	Calculated t-Value
1	U.Mich.	-10018.57
2	SNL	-732.22
3	LLNL	-289.51
4	ASH	-23.21
5	Nantek	0.89
6	GD-5	1.41
7	Diligen	1.88

Table 6-2. Comparison of Decontamination Technologies on Cement

	Mean Contamination, CFU/Panel		Standard Deviation of CFU/Panel	
Technology	Before Decon.	After Decon	Before Decon.	After Decon
U. Mich.	3.66×10^{8}	2.85×10^{2}	4.48×10^{8}	3.28×10^{2}
SNL	2.96×10^{8}	3.70×10^{3}	3.25×10^{8}	4.59×10^{3}
LLNL	1.52×10^{8}	2.67×10^{4}	9.90×10^{7}	1.60×10^{4}
ASH	2.16×10^{7}	1.49×10^{5}	5.21×10^{6}	1.28×10^{5}
Nantek	9.25×10^{7}	2.91×10^{6}	7.08×10^{7}	1.94×10^{6}
GD-5	4.25×10^{8}	4.89×10^{6}	4.98×10^{8}	8.05×10^{6}
Diligen	6.82×10^{7}	3.03×10^{7}	3.27×10^{7}	4.25×10^{7}
Untreated	1.82×10^{8}	3.00×10^{8}	4.25×10^{7}	7.14×10^{7}

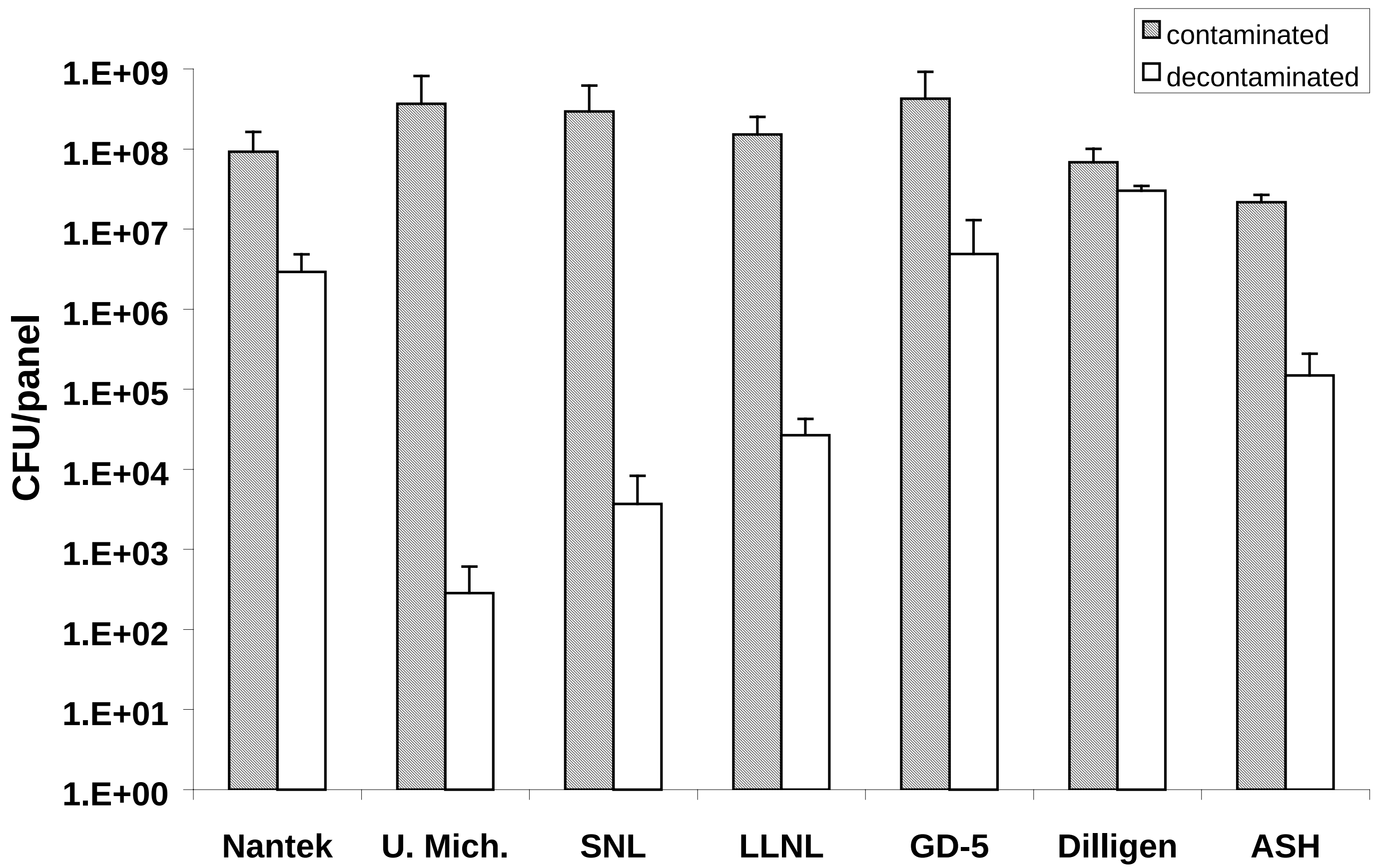

Figure 6 - 1 Comparison of Technologies Decontamination on Cement

6.2 Ceiling Tile

The ranking and t-values for each technology are presented in Table 6-3. Results of the decontamination tests of ceiling tile panels are summarized in Figure 6-2 and Table 6-4.

Table 6-3. Decontamination Ranking for Ceiling Tile Panels

Ranking	Decon	Calculated t-Value
1	U.Mich.	-90839.96
2	SNL	-2234.66
3	LLNL	-1438.47
4	ASH	-220.66
5	GD-5	-95.06
6	Diligen	0.23
7	Nantek	234.33

Table 6-4. Comparison of Decontamination Technologies on Ceiling Tile

Technology	Mean Contamination, CFU/Panel		Standard Deviation of CFU/Panel	
	Before Decon.	After Decon.	Before Decon.	After Decon.
U. Mich.	1.45×10^{8}	4.27×10^{2}	7.32×10^{7}	5.44×10^{2}
SNL	1.36×10^{8}	2.73×10^{4}	7.58×10^{7}	2.61×10^{4}
LLNL	1.06×10^{8}	3.60×10^{4}	6.14×10^{7}	2.74×10^{4}
ASH	1.00×10^{8}	1.58×10^{5}	7.17×10^{7}	1.80×10^{5}
GD-5	8.74×10^{7}	1.10×10^{6}	3.54×10^{7}	7.32×10^{5}
Nantek	1.70×10^{8}	6.53×10^{7}	3.21×10^{7}	6.41×10^{7}
Diligen	1.80×10^{8}	6.55×10^{7}	1.65×10^{8}	5.26×10^{7}
Untreated	1.30×10^{8}	2.24×10^{8}	7.62×10^{8}	6.04×10^{7}

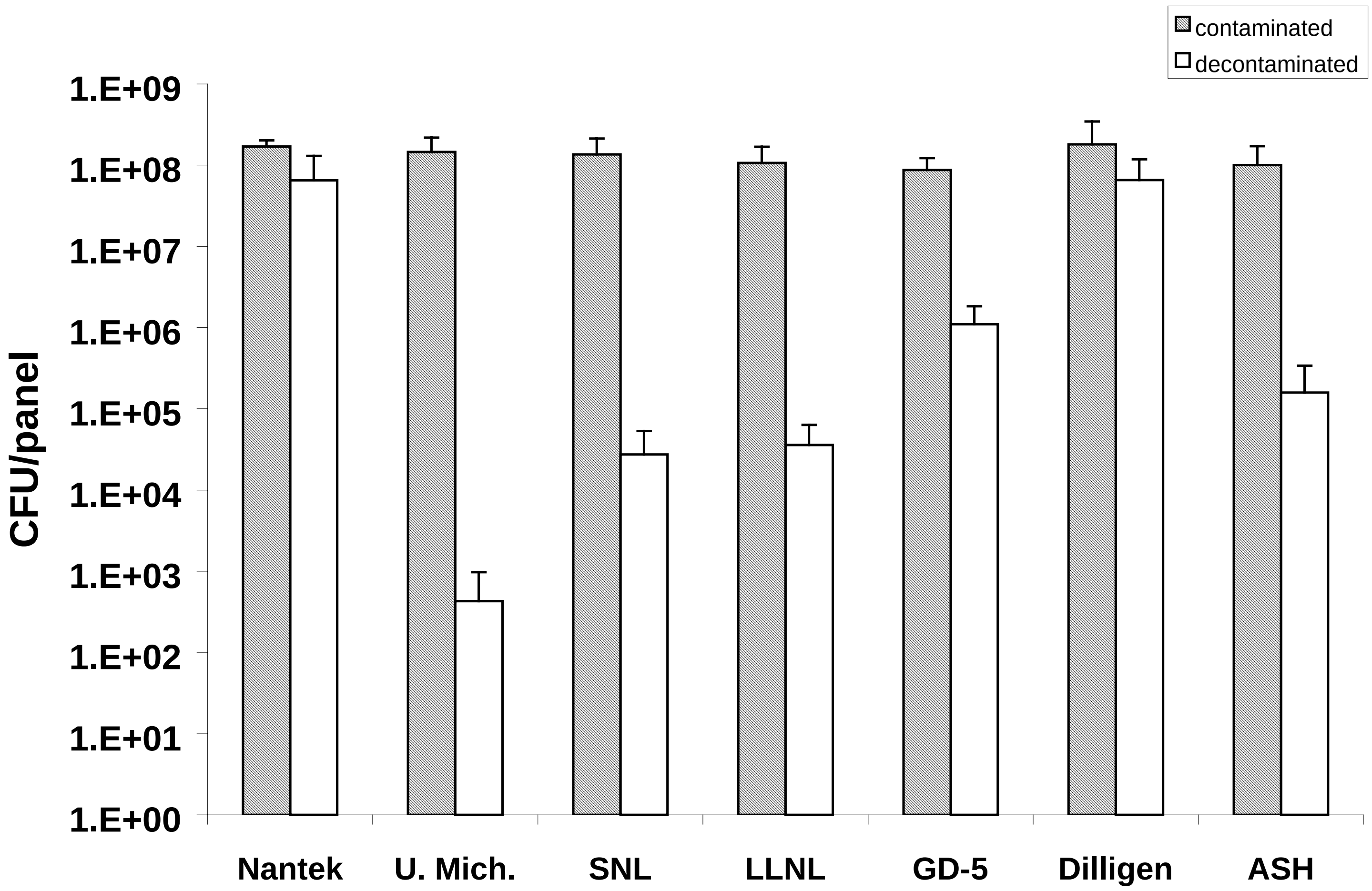

Figure 6 - 2 Comparison of Decontamination Technologies on Ceiling Tile

6.3 Panel Fabric

The ranking and t-values for each technology are presented in Table 6-5. Results of the decontamination tests of panel fabric are summarized in Figure 6-3 and Table 6-6.

Table 6-5. Decontamination Ranking for Panel Fabric

Ranking	Decon	Calculated t-Value
1	U.Mich.	-64550.7
2	SNL	-10160.51
3	ASH	-1455.88
4	LLNL	-523.67
5	GD-5	-26.19
6	Nantek	0.22
7	Diligen	1.69

Table 6-6. Comparison of Decontamination Technologies on Panel Fabric

Technology	Mean Contamination, CFU/Panel		Standard Deviation of CFU/Panel	
	Before Decon.	After Decon.	Before Decon.	After Decon.
U. Mich.	1.53×10^{8}	1.43×10^{2}	8.55×10^{7}	2.84×10^{2}
SNL	3.11×10^{8}	1.85×10^{3}	2.13×10^{8}	1.42×10^{3}
ASH	2.83×10^{8}	2.50×10^{4}	1.51×10^{8}	1.82×10^{4}
LLNL	3.29×10^{8}	3.36×10^{4}	1.71×10^{8}	3.25×10^{4}
GD-5	1.56×10^{8}	1.28×10^{6}	3.81×10^{7}	1.04×10^{6}
Nantek	2.60×10^{8}	2.40×10^{7}	1.79×10^{8}	2.17×10^{7}
Diligen	2.26×10^{8}	4.27×10^{7}	1.38×10^{8}	6.01×10^{7}
Untreated	2.97×10^{8}	4.09×10^{8}	7.01×10^{7}	1.02×10^{8}

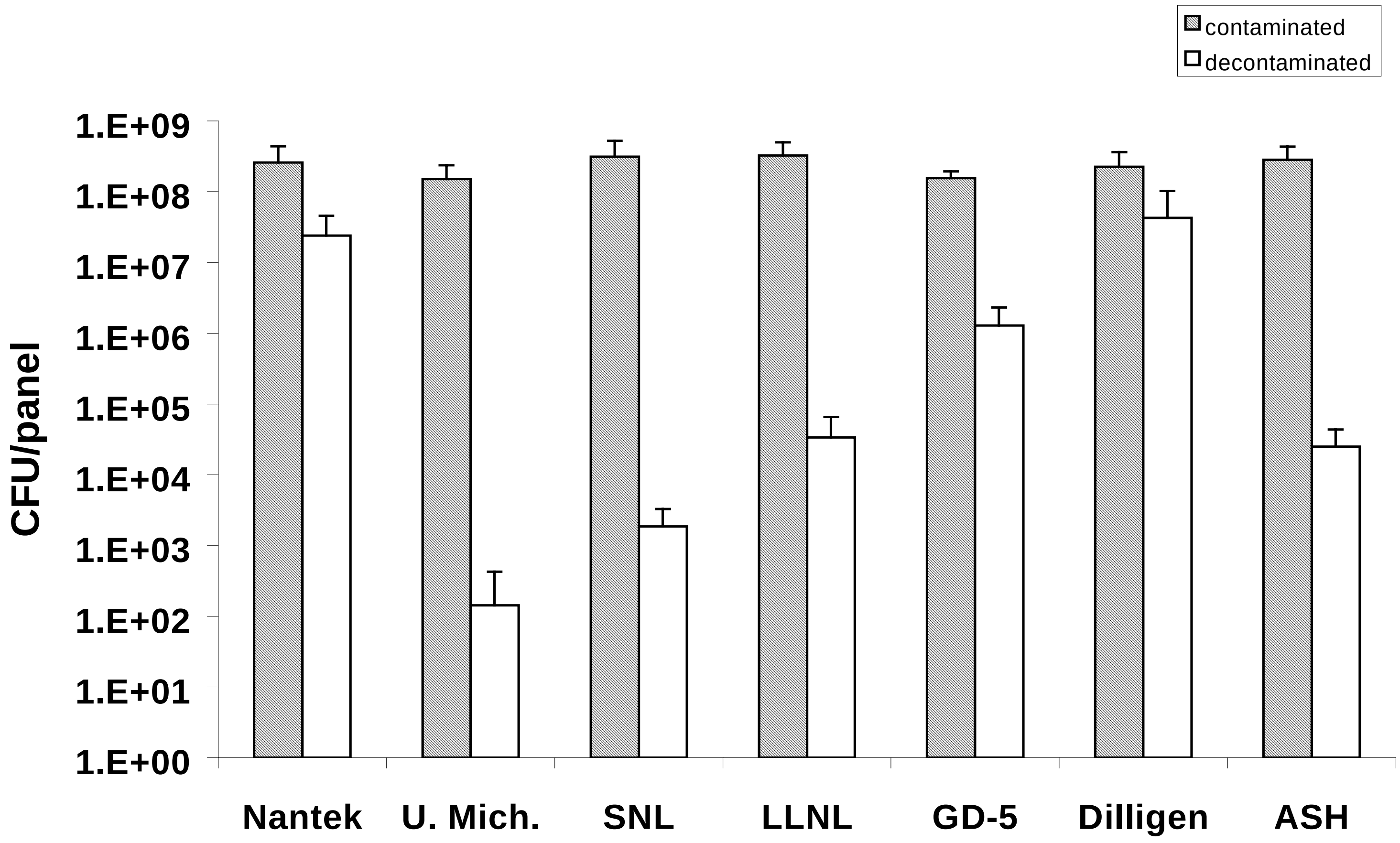

Figure 6 - 3 Comparison of Decontamination Technologies on Panel Fabric

6.4 Painted Metal

The ranking and t-values for each technology are presented in Table 6-7. Results of the decontamination tests of painted metal panels are summarized in Figure 6-4 and Table 6-8.

Table 6-7. Decontamination Ranking for Painted Metal Panels

Ranking	Decon	Calculated t-Value
1	U.Mich.	*
2	SNL	*
3	LLNL	-11950.09
4	ASH	-7454.31
5	GD-5	-2.88
6	Diligen	-1.66
7	Nantek	1.19

* SNL and U.Mich. residual measures of zero for all samples indicate complete removal of the painted metal surface contaminant. The t-statistic calculation requires the standard deviation residual value in the denominator, and for SNL and U.Mich. that value was zero. As a result the calculated t-values for SNL and U.Mich. have been left blank in Table 6-7.

Table 6-8. Comparison of Decontamination Technologies on CARC Painted Metal

Technology	Mean Contamination, CFU/Panel		Standard Deviation of CFU/Panel	
	Before Decon.	After Decon.	Before Decon.	After Decon.
SNL	2.86×10^{8}	$<1.00 \times 10^{0}$	1.85×10^{8}	0
U. Mich.	3.47×10^{8}	$<1.00 \times 10^{0}$	3.27×10^{8}	0
LLNL	2.44×10^{8}	8.25×10^{3}	1.72×10^{8}	1.16×10^{4}
ASH	2.14×10^{8}	2.08×10^{4}	9.51×10^{7}	1.56×10^{4}
GD-5	6.10×10^{8}	5.05×10^{6}	4.93×10^{8}	5.40×10^{6}
Diligen	3.13×10^{8}	3.18×10^{7}	1.98×10^{8}	3.53×10^{7}
Nantek	2.63×10^{8}	3.02×10^{8}	2.40×10^{8}	5.36×10^{8}
Untreated	2.73×10^{8}	3.23×10^{8}	6.51×10^{7}	7.50×10^{7}

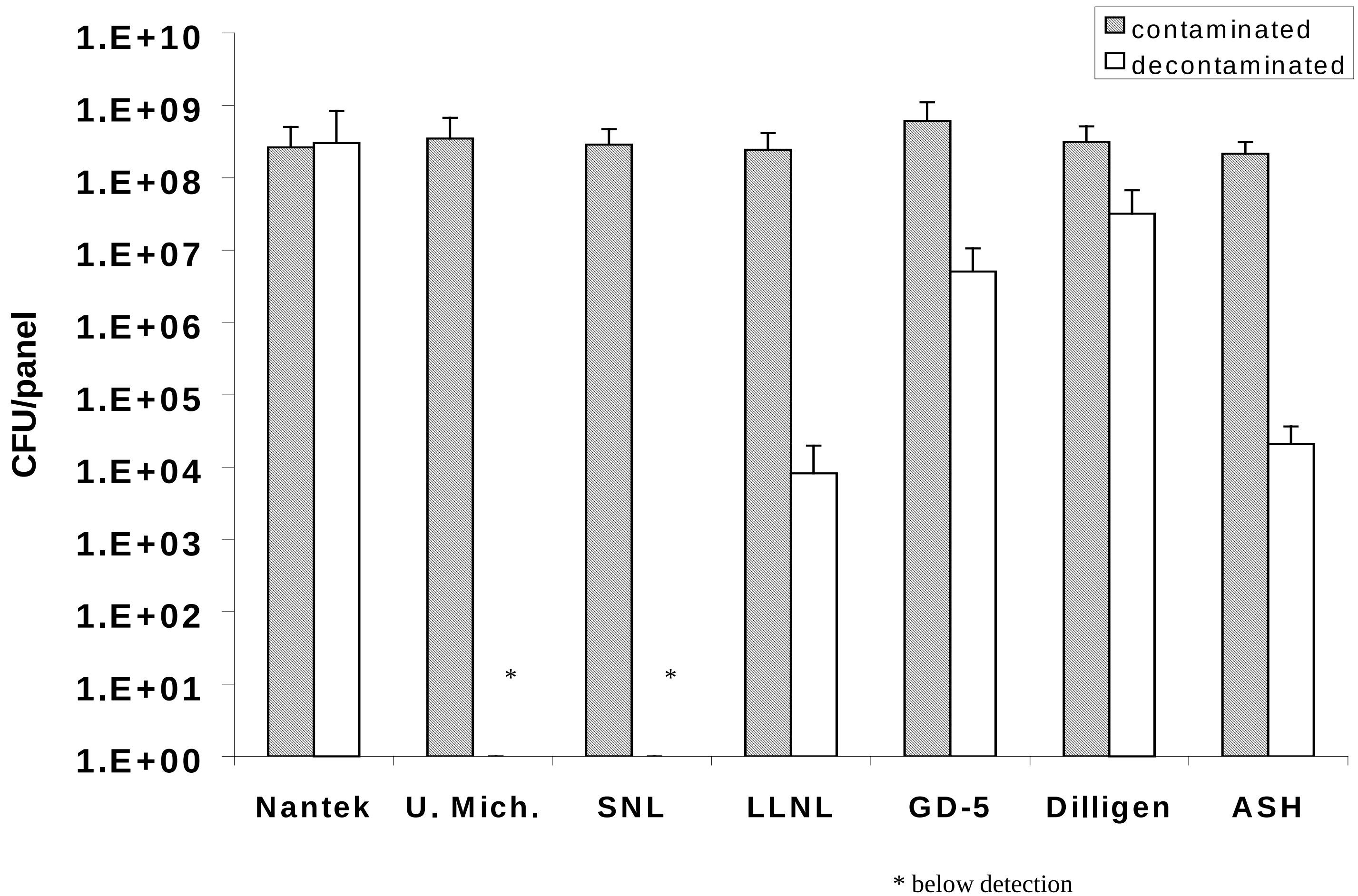

Figure 6 - 4 Comparison of Decontamination Technologies on CARC Painted Metal

6.5 Painted Wallboard

The ranking and t-values for each technology are presented in Table 6-9. Results of the decontamination tests of painted wallboard panels are summarized in Figure 6-5 and Table 6-10. Contamination data for one of the three sample areas in one of the four trials of the U.Mich. technology was lost. As a result, the sample size for U.Mich. on this surface type was 11, but this did not affect the ranking.

Table 6-9. Decontamination Ranking for Painted Wallboard Panels

Ranking	Decon	Calculated t-Value
1	SNL	*
2	U.Mich.	-101552.4
3	LLNL	-1875.31
4	ASH	-1159.96
5	GD-5	-30.25
6	Nantek	-0.06
7	Diligen	0.98

* SNL.residual measures of zero for all samples indicating complete removal of the painted metal surface contaminant. The t-statistic calculation requires the standard deviation residual value in the denominator, and for SNL that value was zero. As a result the calculated t-values for SNL. has been left blank in Table 6-7.

Table 6-10. Comparison of Decontamination Technologies on Painted Wallboard

	Mean Contamination, CFU/Panel		Standard Deviation of CFU/Panel	
Technology	Before Decon.	After Decon.	Before Decon.	After Decon.
SNL	2.51×10^{8}	1.00×10^{0}	1.85×10^{8}	0
U. Mich.	2.02×10^{8}	2.85×10^{2}	1.81×10^{8}	5.68×10^{2}
LLNL	4.38×10^{8}	2.33×10^{4}	4.39×10^{8}	2.22×10^{4}
ASH	3.87×10^{8}	4.82×10^{4}	2.99×10^{8}	3.76×10^{4}
GD-5	2.13×10^{8}	2.83×10^{6}	7.38×10^{7}	1.72×10^{6}
Diligen	3.76×10^{8}	7.29×10^{7}	4.08×10^{8}	1.06×10^{8}
Nantek	2.20×10^{8}	6.95×10^{7}	1.44×10^{8}	6.52×10^{7}
Untreated	2.37×10^{8}	2.67×10^{8}	6.86×10^{7}	6.25×10^{7}

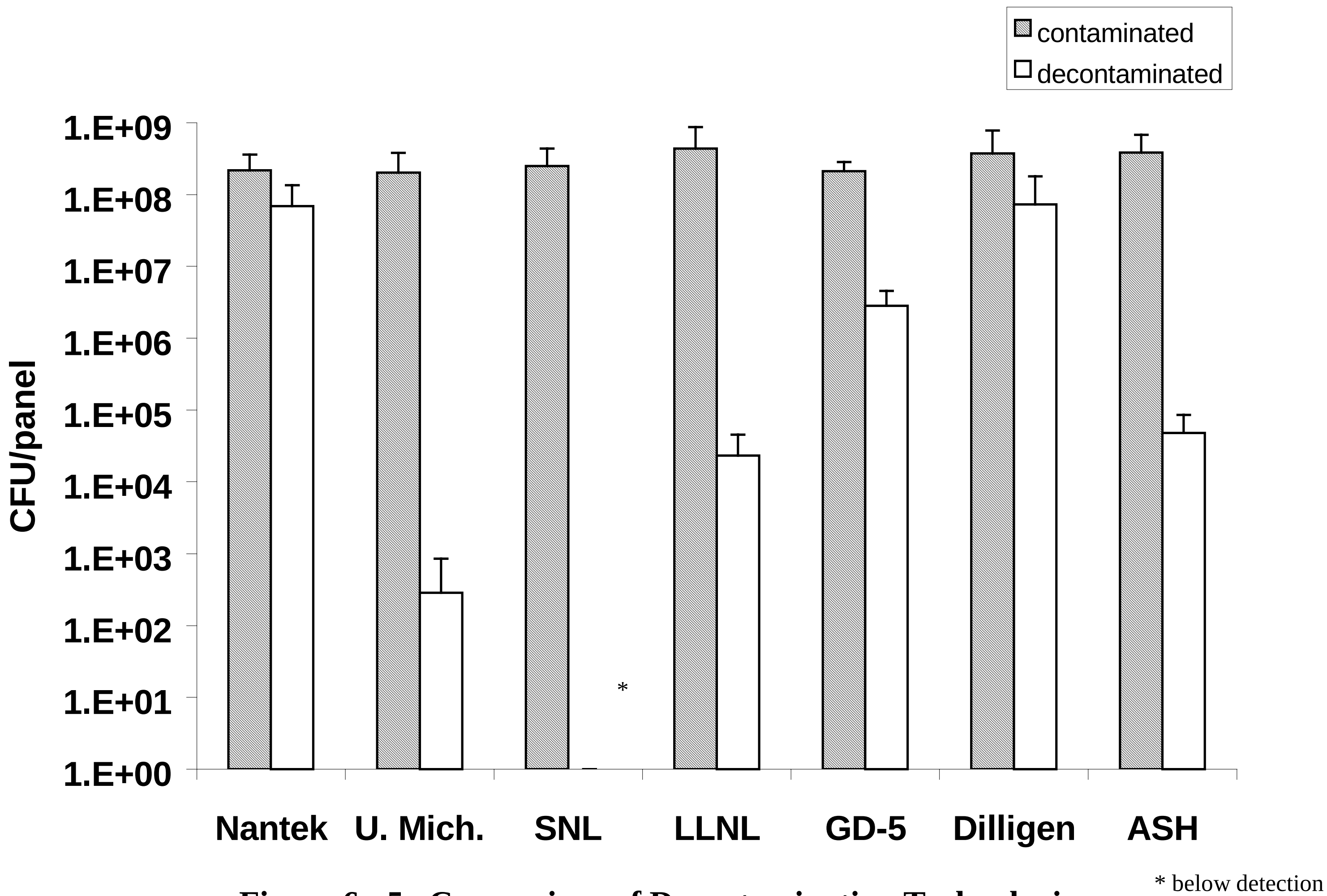

Figure 6 - 5 Comparison of Decontamination Technologies on Painted Wallboard

6.6 Carpet

The ranking and t-values for each technology are presented in Table 6-11. Results of the decontamination tests of carpet panels are summarized in Figure 6-6 and Table 6-12.

Table 6-11. Decontamination Ranking for Carpet Panels

Ranking	Decon	Calculated t-Value
1	LLNL	-9661.08
2	SNL	-6376.01
3	ASH	-5149.94
4	U.Mich.	-570.58
5	GD-5	-50.91
6	Nantek	-1.74
7	Diligen	2.96

Table 6-12. Comparison of Decontamination Technologies on Carpet

Technology	Mean Contamination, CFU/Panel		Standard Deviation of CFU/Panel	
	Before Decon.	After Decon.	Before Decon.	After Decon.
LLNL	2.40×10^{8}	5.69×10^{3}	1.12×10^{8}	3.44×10^{3}
SNL	2.29×10^{8}	5.97×10^{3}	9.97×10^{7}	8.38×10^{3}
ASH	2.04×10^{8}	1.38×10^{4}	1.43×10^{8}	9.66×10^{3}
U. Mich.	2.74×10^{8}	9.05×10^{4}	1.52×10^{8}	1.21×10^{5}
GD-5	1.40×10^{8}	1.79×10^{6}	1.21×10^{8}	1.37×10^{6}
Nantek	1.61×10^{8}	1.69×10^{7}	9.98×10^{7}	5.87×10^{6}
Diligen	2.18×10^{8}	1.42×10^{8}	6.61×10^{7}	3.97×10^{5}
Untreated	1.24×10^{8}	1.91×10^{8}	4.54×10^{7}	6.59×10^{7}

The data from Diligen on the carpet panels had anomalies that may require retesting. The data indicated that there was no contamination removal by the Diligen method on the carpet surface for sample areas 2 and 3 of each trial.

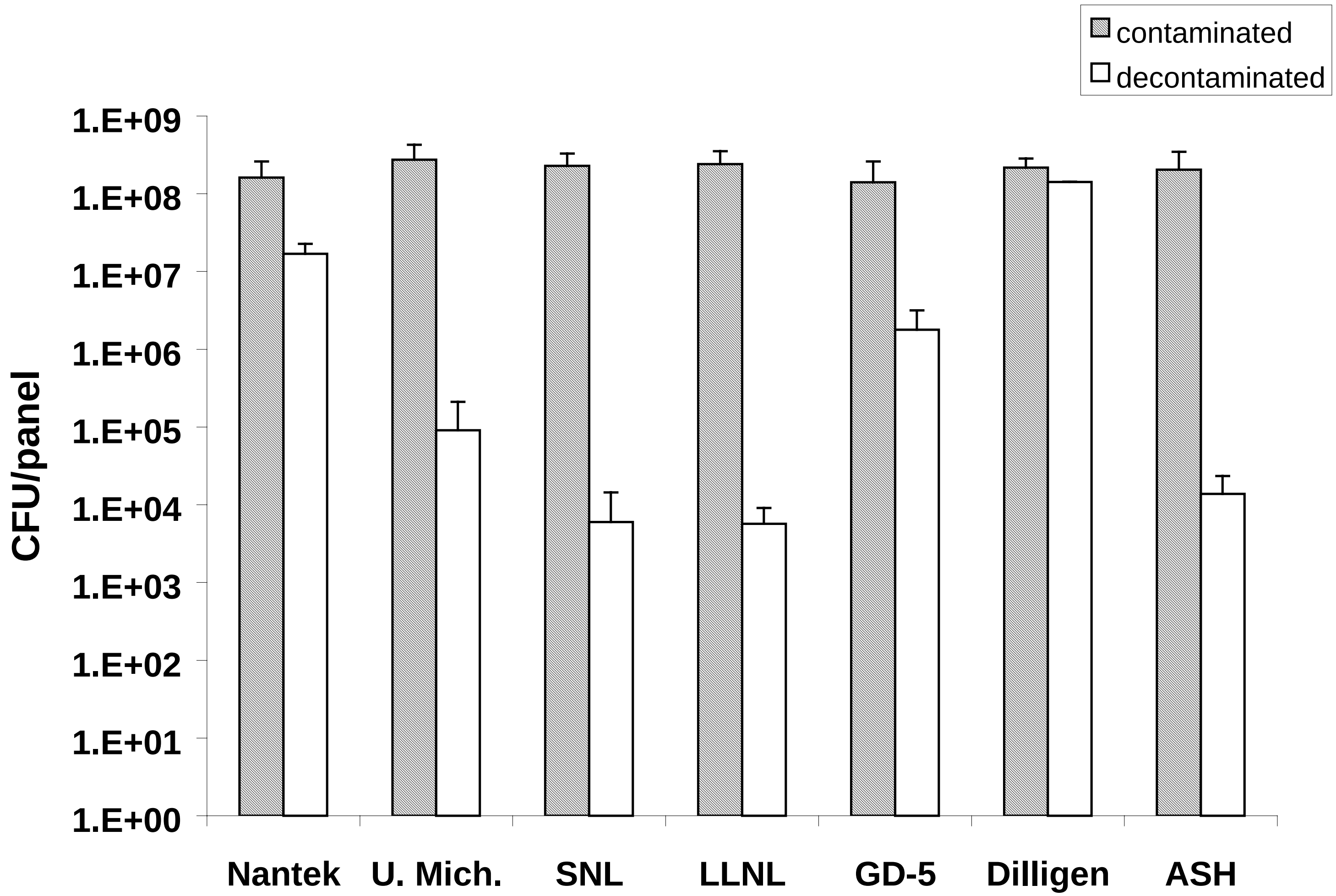

Figure 6 - 6 Comparison of Decontamination Technologies on Carpet

6.7 Overall Ranking

The consolidated ranking table (Table 6-13) provides a summary and an overall ranking based on the sum of the technologies' rankings on each surface type. A score of one (1) to seven (7), with one being the most decontamination and seven the least was given to each technology according to the rank in each surface type column. The best score of 10 was achieved by U.Mich technology.

Table 6-13. Consolidated Ranking of Decontamination Technologies

Technology	Ranking for Each Material						Overall Score
	Cement	Ceiling Tile	Panel Fabric	Painted Metal	Painted Wall	Carpet	
U.Mich.	1	1	1	1	2	4	10
SNL	2	2	2	2	1	2	11
LLNL	3	3	4	3	3	1	17
ASH	4	4	3	4	4	3	22
GD-5	6	5	5	5	5	5	31
Nantek	5	7	6	7	6	6	37
Diligen	7	6	7	6	7	7	40

7.0 CONCLUSIONS

Performing best in the overall rankings were University of Michigan (U.Mich.), Sandia National Laboratories (SNL) and Lawrence Livermore Laboratory (LLNL). Consistently at the bottom of the ranking tables were Diligen and Nantek methods of decontamination.

The data suggest that the material surfaces most receptive to decontamination of agent simulant BG are Painted Metal, Painted Wallboard and Panel Fabric. The decontamination technologies were less effective on the porous surfaces. None were able to fully-decontaminate all surfaces in this test.

The overall ranking of Decontamination Methods/Systems was done using a simple uniform-weighting technique. A more detailed analysis does not seem warranted by the general nature of the test procedures and results.

The contamination procedures are obviously a source of variation. The test plan requires the target value for BG deposition densities in the range of 10^7 to 10^8 CFU per sample area. There are sample data points on both extremes of this range. Tighter controls on the contamination process might reduce the range of contamination values.

8.0 REFERENCES

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